

Victims crossing overflowing watercourses with vehicles in Spain

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Abstract

Heavy rainfall causes many watercourses to overflow. In these circumstances, crossing by car even on a road, can be extremely dangerous; however, dozens of drivers are swept away every year in their vehicles. This paper analyses this type of accident in Spain between 2008 and 2018, recording the date, location, number of victims, age and gender, and rainfall during the event. The results show that 125 accidents occurred with 200 victims including 45 fatalities. Most accidents occurred in E, S and SE Spain, where the rainfall irregularity is greater, during December, October and March, although fatalities were concentrated in September and October. Among the victims male drivers dominated, with an average age of 52 years. The main cause of these accidents was the drivers' behaviour due to: underestimating risk, overconfidence, overvaluation of their driving skills, an excess of trust in the authorities, ignorance about vehicle drag and buoyancy risks, and, social pressure. To reduce these risks, it is necessary to increase adaptation and protection measures on roads, but above all, a change in drivers' behaviour to stop them trying to cross-flooded rivers.

KEYWORDS

drowning, flood fatalities, overflow, rain irregularity

1 | INTRODUCTION

Roads are linear elements that intersect watercourses in their layout. These crossings can be done through bridges, drainage works or fords, depending on the importance of both the road and the watercourse. Main roads usually have wide river crossing works, which guarantee traffic safety during intense rainy episodes. However, many secondary and unpaved roads have smaller drainage works and bridges, and even cross non-permanent streams by fords.

Rainfall distribution in the Mediterranean region is very irregular, with high concentrations in a few days (García-Barrón, Aguilar-Alba, Morales, & Sousa, 2017), which favours rivers overflow. There are a large number of non-permanent watercourses where water only circulates some days a year, during intense rain episodes, but in those situations the flow can be torrential. Many of these watercourses are crossed, directly or through minor drainage works, by local roads; they are passable almost always, except when there is heavy rain. In addition, during extraordinary episodes river levels rise and can

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exceed drainage works and bridges, flooding the roads, even the main ones.

Climate change is affecting this region intensely, producing a reduction in average rainfall (11% between 1961 and 2006), although irregularly, with a significant reduction in February, June and March and an increase in May, August, September and October (Río, Herrero, Fraile, & Penas, 2011). There are discrepancies about changes in the intensity and frequency of extreme rainfall, due to the high uncertainty: van den Besselaar, Klein, and Buishand (2012) and the fifth IPCC report (Christensen et al., 2013; Hartmann et al., 2013) indicated that the irregularity in the region will increase, and Barrera-Escoda, Gonçalves, Guerreiro, Cunillera, and Baldasano (2014) found an increase of the frequency of heavy precipitation events during the 2021–2050 period in Catalonia (Spain), but Valdés-Abellán, Pardo, and Tenza-Abril (2017) point to a decreased frequency of heavy precipitation events in the last 20 years.

Also important are changes in land use, with great influence on runoff; at basin scale these changes are more important than those associated with climate (Whitfield, 2012). Consequently, river overflowing at road crossings is common throughout the Mediterranean region, and increases predictably in the future.

Dozens of drivers around the world are swept away in their vehicles every year when attempting to cross overflowing rivers or flooded areas, and many of them die drowned (Ashley & Ashley, 2008; Diakakis & Deligiannakis, 2013; Drobot, Benight, & Gruntfest, 2007; FitzGerald, Du, Jamal, Clark, & Hou, 2010; Hamilton, Peden, Pearson, & Hagger, 2016; Jonkman & Kelman, 2005; Petrucci et al., 2018, 2019; Ruin, Gaillard, & Lutoff, 2007; Salvati et al., 2018; Staes, Orengo, Malilay, Rullan, & Noji, 1994; Yale, Cole, Garrison, Runyan, & RiadRuback, 2003). Human behaviour contributes greatly to fatalities during floods: accidents crossing overflowing rivers are mainly due to overconfidence and underestimation of risk (Ashley & Ashley, 2008; Diakakis & Deligiannakis, 2013; Horswill, Waylen, & Tofield, 2002; Ruin et al., 2007; Siegrist, Gutscher, & Earle, 2005; Terpstra, 2011); vehicle submersion is often a consequence of deliberately driving into flooded roadways (Yale et al., 2003). The number of vehicle related fatalities during floods is quite important, reaching between 25 and 68%, depending on the countries (Smith, Modra, & Felder, 2019).

The aim of this paper is to analyse accidents crossing overflowing rivers by car between 2008 and 2018 in Spain. Based on the results, the most usual risk profile by gender and age has been established, proposing mitigation and adaptation measures, with an special attention to drivers' behavioural adaptation.

2 | METHODS

The study area is Spain, and the period 2008–2018. Accidents crossing overflowing rivers on vehicles during this period have been analysed. An accident is considered to occur when a vehicle that was crossing a watercourse, by its natural channel or in an area where as a result of a flood was overflowed over a track or road, is trapped, immobilised, submerged or dragged, affecting its occupants, who are forced to escape, be rescued or die. Accidents that occurred when vehicles fell into rivers during accidents not associated with rain or river overflow (e.g., collisions in which vehicles fell into the water or distractions from drivers that caused them to rush into waterways), or when the vehicles were dragged by the water while they were parked have been excluded.

A database was developed, which included the information found on each accident. The established fields were: accident date; accident location (place, province and region); driver data (gender, age and damage suffered -died, rescued or escaped themselves-); passenger 1 to 4 data (gender, age and damage suffered); media information (name and publication date); and rainfall in the location during the accident date.

The information sources are news from national or regional newspapers, radio or TV channels, or major news agencies; no reference outside these media has been considered.

To carry out news searches a general search engine has been used (Google). The searches have been done applying several filters, language (conducting the searches in Spanish, and referred to Spain), and date (carrying them out year by year for all the studied period). Keywords established to conduct the searches (originally in Spanish) were: 'sweep away'/'rescued'/'disappeared'/'drowned'; 'crossing'; 'river'/'stream'/'watercourse'; 'car'/'vehicle'/'motorcycle'. Different combinations of these terms have been done, repeating the searches until no new results were obtained. Each search with a combination of some of the indicated terms resulted in around 100 entries, so with all the possible combinations several hundreds of results per year were obtained, many of them repeated. The results were filtered on a case-by-case basis by reading the titles of the entries; the process was quick and simple, because most results lack a relationship with the studied topic, focusing only on those related to accidents.

The results related to accidents with vehicles crossing rivers were analysed in detail. Firstly, the information source (media) quality was analysed, to accept it or not; only information from the media indicated above has been considered, omitting web pages, videos or other sources whose reliability could not be proven. Secondly,

the news reports were read, completing an entry in the database with the information obtained in each one. The data obtained for each entry were, at least, the date and location of the accident, the number of victims, and the name of the media and publication date. Depending on the event the amount of information obtained was more or less; the news about accidents with fatalities used to be more complete, including data on gender and age of the victims. Frequently the same event was published in different media, especially the most tragic; all of them were consulted, to complete the maximum number of fields in each database entry. The reference included was that of the media that provided more complete information, or more than one when they were complementary. In events with poor information complementary searches have been done, limiting the date and entering new terms, such as the location of the accident.

Voumard, Derron, and 6 Jaboyedoff (2018) applied a similar methodology to analyse natural hazard events affecting transport networks in Switzerland; Diakakis and Deligiannakis (2015) used press articles to identify flood fatalities in Greece; and Pereira, Zêzere, Quaresma, Santos, and Santos (2016) use also newspapers information to construct a database on flood and landslide consequences in Portugal. Other authors used data from social media to assess flood impacts or risks (e.g., Smith, Liang, James, & Lin, 2017 for UK, or Fang, Hu, Shi, & Zhao, 2019 for China).

Once the search for information was completed, each database entry was completed including the rainfall record for the accident location and date. The information was obtained from the State Meteorological Agency databases (AEMET, 2019), consulting the meteorological station with daily rainfall records closest to the accident site, on the date on which it took place or the day before (to take into account concentration runoff times and possible delayed floods). When the searches did not provide results, due to a lack of data, the next nearest station was chosen, until results were obtained.

3 | RESULTS

Between 2008 and 2018, 125 accidents produced when trying to cross overflowing watercourses with vehicles were registered, 33 of them with fatalities (Table 1). As a result, 200 people were involved in these accidents; 45 died, 137 were rescued and 18 escaped by themselves. The average number of victims per accident is 1.6, and the death rate per accident was 0.23. The victims were 92% Spanish and 8% foreign (most of them from the EU).

There has been an increase in the number of accidents over the period studied, although those with

fatalities have increased with less intensity. The number of fatalities was irregular over the period (2018 recorded the highest number of victims of the decade), but the number of rescued victims was markedly higher in 2016 and 2018 (Figure 1). Average values throughout the studied period were 11.4 accidents/year, 18.2 victims/year and 4.1 deaths/year; however, in 2018 these figures were 43, 64 and 12, respectively, 2.9–3.7 times higher than the average values.

Three regions concentrated most accidents (Figure 2), E Spain (33.6%), S Spain (21.6%) and SE Spain (16.8%); the provinces with more accidents were Valencia (21.6%, E Spain) and Almería (12.0%, SE Spain). The region with more accidents involving fatalities was S Spain (30.3%) and the provinces Murcia and Balearic Islands (15.2% each one).

Months with most accidents were December, October and March, while accidents with fatalities were mainly concentrated on September and October (Figure 3). The average of the daily rainfall during the accidents that have taken place in each month has been calculated. Analysing these results in parallel to the number of accidents, a close relationship is observed, especially in accidents with fatalities (Figure 3).

Average daily rainfall during accidents is 43.5 mm, with maximums of 259 mm (Málaga in 2018) and 241.6 mm (Almería in 2012). There are some accidents where rainfall is null or very low, which may have several explanations. Firstly, the network of meteorological stations with daily rainfall data is limited; the stations closest to the accidents may not have data on the date they occurred. Secondly, the river overflowing may be due to spatially remote precipitation, for example at the head of the basin; this means that even if it does not rain in a certain area, the watercourses may be overflowed. Finally, some accidents may be due to the river flow without the influence of exceptional rainfall; this could be the case of an accident in Córdoba in 2010, with scarce rainfall, but a large river with an important flow regularly, which the victim tried to cross.

Average annual rainfall in the provinces with most accidents and more fatalities is (in brackets the average number of rainfall days per year): Valencia 475 mm (43.9); Almería 200 mm (25.4); Murcia 297 mm (36.5); Mallorca (Balearic Islands) 411 mm (50.9); consequently, rainfall during accidents is, on average, 8.5–20.4% of annual rainfall, reaching 48.5% in Málaga in 2018, an even 120.8% in Almería in 2012, a daily event greater than the annual average rainfall. Regarding the maximum rainfall in 24 hr, the annual average for all the regions is about 35 mm, with a maximum of 51 mm in the east, although it is a very irregular parameter; the mean of the extreme maximums is 170 mm, with an exceptional value of

TABLE 1 Victims crossing overflowing watercourses with vehicles in Spain (2008–2018)

Date	Victims	Location	Media reference and date	Rainfall
September 22, 2008	1 driver (?♂) rescued (injured)	Lucena, Córdoba, S Spain	Diario de Córdoba, September 23, 2008	20.4 mm
September 28, 2008	1 driver and 3 occupant rescued (?♂, ? ♀ 2?, 8?)	Castor River, Málaga, S Spain	Opinión de Málaga, September 28, 2008	12.8 mm
October 18, 2008	1 driver (27♀), 2 occ. (6?, 8?) res, 1 occ. (? 1) dead	Calig, Castellón, E Spain	ABC, October 19, 2008	15.4 mm
October 19, 2008	2 drivers rescued	Chiva, Valencia, E Spain	Las Provincias, October 21, 2008	13.9 mm
October 22, 2008	1 driver (64♂) escaped	Benialí, Alicante, E Spain	Levante, October 24, 2008	15.3 mm
November 29, 2008	1 driver and 1 occupant rescued	Nora River, Asturias, N Spain	El Comercio November 30, 2008	22.7 mm
February 01, 2009	1 driver (56♂) rescued	Manilva River, Málaga, S Spain	Manilva, February 01, 2009	54.8 mm
September 13, 2009	1 driver (43♂) dead	Stream in Torrico, Toledo, C Spain	ABC, September 14, 2009	4.8 mm
September 15, 2009	1 driver (74♂) and 1 occupant (74♀) dead	Valdeastillas, Jaén, S Spain	RTVE, September 21, 2009	30.1 mm
	1 driver (35♂) dead	Guadalimar River, Jaén, S Spain	RTVE, September 21, 2009	30.1 mm
September 16, 2009	1 driver (25♀) dead	Maraña River, Murcia, SE Spain	Opinión de Murcia, September 17, 2009	20.1 mm
December 24, 2009	1 driver (?♂) rescued	Andarax River, Almería, SE Spain	Diario de Almería, December 26, 2009	46.2 mm
April 15, 2010	1 driver and 1 occupant (?♂, ? ♀) rescued	Manilva River, Málaga, S Spain	Malaga Hoy; Mundo, April 16, 2010	45.4 mm
	1 driver (31♂) esc. And 2 occ. (29♂, 56♀) dead	Aguilar, Córdoba, S Spain	El Pais, August 18, 2010	27.8 mm
August 17, 2010	1 driver (?♀) and 1 occupant (?♀) escaped	Sepultura stream, Almería, SE Spain	Diario de Sevilla, August 18, 2010	0.9 mm
	3 driver and 3 occupant (3 cars) rescued	Puente stream, Almería, SE Spain	Diario de Sevilla, August 18, 2010	0.9 mm
September 21, 2010	1 driver (28♂) dead	Guadalquivir River, Córdoba, S Spain	ABC, September 23, 2010	0.6 mm
October 12, 2010	1 driver (≈50♀) rescued	Ulldemó River, Teruel, E Spain	Crónica de Aragón, October 13, 2010	48.1 mm
December 12, 2010	1 driver (61♂) rescued	Jabalón stream, Ciudad Real, C Spain	RTVCM, December 09, 2010	37.2 mm
December 21, 2010	1 driver (40♀) rescued	Piedras stream, Malaga, S Spain	Diario Sur, October 22, 2010	47.8 mm
March 03, 2011	1 driver (?♂) rescued	Pulpí, Almería, SE Spain	Diario de Almería, March 05, 2011	17.7 mm
March 06, 2011	1 driver and 2 occupants rescued	Valverde, Huelva, SW Spain	ABC, March 07, 2011	36.0 mm
	1 driver (41♀) and 3 occ. (81♂, 78♀, 6♂) dead	Onda, Castellón, E Spain	RTVE; El Pais; SER, November 20, 2011	22.0 mm
November 20, 2011	1 driver (29♂) dead	Ratils stream, Castellón, E Spain	El Imparcial, November 21, 2011	22.0 mm
	1 driver rescued	Jativa, Valencia, E Spain	El Imparcial, November 21, 2011	47.3 mm
	1 driver rescued	Picasent, Valencia, E Spain	El Imparcial, November 21, 2011	47.3 mm
	1 driver (50♀) dead	Béjar River, Murcia, SE Spain	La Verdad, September 29, 2012	100.6 mm
	1 driver (85♂) dead	Reguerón Channel, Murcia, SE Spain	ABC, September 29, 2012	64.2 mm
September 28, 2012	1 driver (65♂), 1 occ. (9♀) dead, 1 occ. Escaped	P. Lumbreras River, Murcia, SE Spain	La Verdad, September 29, 2012	100.6 mm
	1 driver (65♂) dead	Sagonera, Murcia, SE Spain	La Verdad, September 29, 2012	64.2 mm
	1 driver (71♂) and 1 occ. (≈60–70♀) dead	Guazamara River, Almería, SE Spain	La Verdad, September 29, 2012	241.6 mm

TABLE 1 (Continued)

Date	Victims	Location	Media reference and date	Rainfall
November 14, 2012	1 driver (?♂) rescued	Palma Gandía, Valencia, E Spain	Europa Press, November 14, 2012	106.0 mm
March 13, 2013	1 driver (54♂) dead	Fardes River, Granada, S Spain	Granada Hoy, March 13, 2013	13.6 mm
March 15, 2013	1 driver (?♂) rescued	Beiro-Genil Rivers, Granada, S Spain	Ideal, March 15, 2013	6.4 mm
March 30, 2013	1 driver (≈55♂) and 3 occupants rescued (♀, ♀, ♂)	Alhama River, Navarra, N Spain	Diario de Navarra, March 31, 2013	15.0 mm
August 28, 2013	1 driver (58♂) dead	Cubillas River, Granada, S Spain	El Pais, August 30, 2013	8.5 mm
September 25, 2014	1 driver (≈50♂) rescued	Gallardos, Almería, SE Spain	La Vanguardia, September 25, 2014	20.3 mm
March 20, 2015	1 motorist (60♂) rescued	Almería, SE Spain	Europa Press, march 20, 2015	57.6 mm
	2 drivers rescued	Balerna, Almería, SE Spain	Europa Press, March 20, 2015	21.0 mm
April 24, 2015	3 drivers (≈30♂, ≈30♂, ≈45♀) and 2 occ. Rescued	Masamagrell, Valencia, E Spain	Las Provincias, April 24, 2015	0.0 mm
September 07, 2015	1 driver (61♂) dead	Polopos, Granada S Spain	El Mundo, September 07, 2015	79.5 mm
April 17, 2016	1 driver (32–40♂) and 1 occ. Resc., 2 occ. Escaped	Guadarrama River, Madrid, C Spain	Telemadrid, Ser, April 18, 2016	16.5 mm
May 11, 2016	1 driver (66♂) dead	Trigueros, Huelva, SW Spain	ABC, December 17, 2016	26.8 mm
October 12, 2016	1 driver (60♂) dead	Cabrils stream, Barcelona, NE Spain	La Provincia, October 12, 2016	108.6 mm
October 23, 2016	1 driver (65♂) dead	Culebras stream, Seville, SW Spain	ABC, October 25, 2016	72.5 mm
November 26, 2016	1 driver (19♂) escaped, 1 occupant (20♀) dead	Can Ferraguet, Barcelona, NE Spain	El Mundo, November 27, 2016	17.2 mm
	1 driver (?♀) rescued	Sagunto, Valencia, E Spain	SER, November 28, 2016	78.0 mm
December 01, 2016	1 driver and 3 occupant rescued	Mojácar, Almería, SE Spain	Europa press, December 01, 2016	21.8 mm
December 06, 2016	1 driver (?♂) esc., 1 occ. Dead (53♀), 3 occ. Esc.	Tietar River, Cáceres W Spain	ABC, December 07, 2016	11.0 mm
	1 driver (42♂) rescued	Pulpí, Almería, SE Spain	El Mundo, December 20, 2016	84.9 mm
	1 driver (?♂) rescued	Espinardo River, Murcia, SE Spain	Opinión de Murcia, December 17, 2016	56.0 mm
	1 driver (?♂) resc., 2 driver (?♂, ♂), 1 occ. Escaped	Buñol River, Valencia, E Spain	Levante, December 17, 2016	49.8 mm
	2 drivers rescued (2 cars)	Villareal, Castellón, E Spain	Levante, December 18, 2016	41.6 mm
December 17, 2016	2 drivers and 2 occupant (2 cars) rescued	Turís, Valencia, E Spain	Levante, December 18, 2016	49.8 mm
	1 driver rescued	Algar Palancia, Valencia, E Spain	Levante, December 18, 2016	46.2 mm
	1 driver and 2 occupant rescued	Magre River, Valencia, E Spain	Levante, December 19, 2016	49.8 mm
	1 driver and 1 occupant rescued	Albox, Almería, SE Spain	Correo de Andalucía, December 19, 2016	84.9 mm
	1 driver and 5 occupants rescued	Roquetas, Almería, SE Spain	Correo de Andalucía, December 19, 2016	70.6 mm
December 18, 2016	1 driver (64♂) dead	Enguera, Valencia E Spain	La Vanguardia, December 20, 2016	70.4 mm
	1 driver (73♂) rescued	Beniel, Murcia, SE Spain	Opinión de Murcia, December 19, 2016	109.2 mm
	1 driver and 2 occupant rescued	Betera, Valencia, E Spain	El Mundo, December 19, 2016	54.4 mm
	1 driver (51♂) escaped	Ibiza, Balearic Islands, E Spain	Periódico de Ibiza, December 19, 2016	75.9 mm

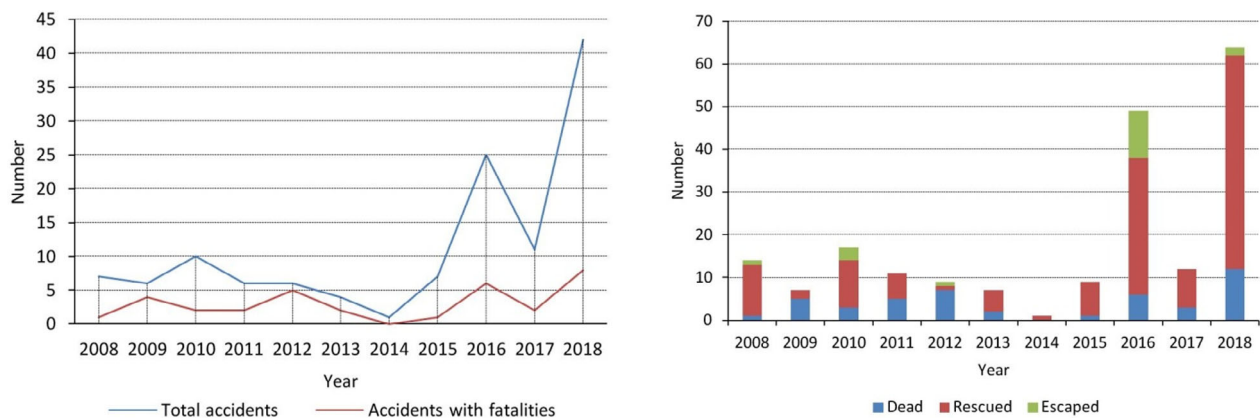
(Continues)

TABLE 1 (Continued)

Date	Victims	Location	Media reference and date	Rainfall
January 20, 2017	1 driver (?♀) rescued	Carraixet, Valencia, E Spain	Periódico de Aquí, January 20, 2017	72.0 mm
January 21, 2017	1 driver (53♂) rescued	Guadalest River, Alicante, E Spain	Diario Información, January 22, 2017	23.6 mm
January 27, 2017	1 driver (60♂) and 1 occupant (59♀) dead	Masarac stream, Gerona, NE Spain	Diario de Ibiza, January 30, 2017	22.6 mm
March 13, 2017	1 driver (67♂) rescued	Serpis River, Alicante, E Spain	Levante, March 13, 2017	69.0 mm
July 08, 2017	1 driver (57♂) dead	Coslada, Madrid, C Spain	TeleMadrid; La Razón, July 08, 2017	17.5 mm
September 27, 2017	1 driver (?♂) rescued	Guillena, Seville, SW Spain	Diario Sevilla, Correo, September 27, 2017	0.0 mm
	1 driver (≈30♂) rescued	Ribarroja, Valencia, E Spain	Levante, December 21, 2017	1.4 mm
December 21, 2017	1 driver rescued	Cálig, Castellón, E Spain	Levante, December 21, 2017	0.0 mm
	1 driver rescued	Almanzora, Castellón, E Spain	Levante, December 21, 2017	0.0 mm
	2 drivers rescued	Nules, Castellón, E Spain	Levante, December 21, 2017	0.0 mm
February 28, 2018	2 drivers (60♂, ? ♂), 1 occ. (60♀) rescued (2 cars)	Cidacos River, Rioja, N Spain	La Rioja, February 28, 2018	12.2 mm
March 01, 2018	1 driver (?♂) rescued	Vélez, Málaga S Spain	Andalucía Información March 01, 2018	45.4 mm
	1 driver (?♂) rescued	Torre de mar, Granada, S Spain	Diario Sur, March 02, 2018	40.5 mm
March 02, 2018	1 driver (?♂) rescued	Sabar River, Málaga S Spain	Diario Sur, March 02, 2018	46.0 mm
	1 driver (?♂) rescued	Mineral stream, Málaga, S Spain	Diario Sur, March 02, 2018	46.0 mm
March 10, 2018	1 driver (?♀) rescued	Jerte River, Cáceres, W Spain	20 minutos, March 12, 2018	42.1 mm
March 11, 2018	1 driver (?♂) rescued	Isuela River, Huesca, N-NE Spain	Heraldo, March 12, 2018	9.4 mm
March 15, 2018	1 driver (?♂) rescued	Porzuna, Ciudad Real, C Spain	ENCLM, March 15, 2018	18.4 mm
March 17, 2018	1 motorist (23♂) dead	Martos, Jaén, S Spain	RTVE, La Sexta, March 18, 2018	42.2 mm
	1 driver (?♂) rescued	Guillena, Seville, SW Spain	Europa Press, March 18, 2018	19.9 mm
March 18, 2018	1 driver (?♂) rescued	Verde River, Granada, S Spain	Andalucía Información, March 18, 2018	25.5 mm
March 23, 2018	1 driver (?♂) rescued	Cabra River, Córdoba, S Spain	Diario de Córdoba, March 23, 2018	10.2 mm
April 11, 2018	1 driver (?♂) rescued	Gaià River, Tarragona, NE Spain	Diari Mes, April 11, 2018	17.7 mm
April 13, 2018	1 driver and 2 occupants rescued (? , 15♂)	Ontígola, Toledo, C Spain	ABC, April 13, 2018	4.2 mm
	1 driver (?♂) escaped	Canonja, Tarragona NE Spain	Diari Tarragona, April 13, 2018	7.8 mm
April 16, 2018	1 driver (≈50♂) rescued	Limonetes stream, Badajoz, W Spain	Crónica de Badajoz, April 17, 2018	9.0 mm
April 24, 2018	1 driver escaped	Cidacos River, Rioja, N Spain	La Rioja, April 24, 2018	0.0 mm
May 27, 2018	1 driver and 3 occupants rescued	Guarga River, Huesca, N-NE Spain	Heraldo, May 27, 2018	14.2 mm
May 30, 2018	1 driver (38♂) rescued	Ballobar stream, Huesca, N-NE Spain	ABC, June 01, 2018	18.6 mm
June 02, 2018	2 drivers and 2 occupants rescued (2 cars)	Berciumel, Segovia, C Spain	Acueducto, June 02, 2018	9.8 mm
June 02, 2018	1 driver (77♂), 2 occupants (83♂, 88♀) rescued	Alginet, Valencia, E Spain	Levante, June 04, 2018	52.7 mm
	1 driver (?♂) and 1 occupant (?♂) rescued	Úbeda, Jaén, S Spain	La Contra de Jaén, August 16, 2018	35.8 mm
August 16, 2018	1 driver (?♂) rescued	Peal de Becerro, Jaén, S Spain	La Contra de Jaén, August 16, 2018	35.8 mm
August 17, 2018	1 driver (43♂) dead	Rubí, Barcelona, NE Spain	Diari de Terrassa, August 19, 2018	25.8 mm

TABLE 1 (Continued)

Date	Victims	Location	Media reference and date	Rainfall
September 17, 2018	1 driver ($\approx 50\delta$) and 3 occupant ($\approx 75\varphi, ?, ?$) rescued	Logroño, Rioja, N Spain	La Rioja, September 17, 2018	3.5 mm
	1 driver (40 φ), 1 occ. (5 δ) dead, 1 occ. (7 φ) resc.	Mallorca, Balearic Islands, E Spain	Diario de Mallorca, October 11, 2018	34.6 mm
	1 driver (62 δ) and 2 occupant (75 φ , 77 δ) dead	Mallorca, Balearic Islands, E Spain	ABC, October 12, 2018; UH, October 14, 2018	34.6 mm
	1 driver (57 δ) dead	Mallorca, Balearic Islands, E Spain	ABC, October 12, 2018; UH, October 14, 2018	34.6 mm
October 09, 2018	1 driver (56 δ) dead	Mallorca, Balearic Islands, E Spain	Última Hora, October 14, 2018	34.6 mm
	1 driver (61 δ) and 1 occupant (63 φ) dead	Mallorca, Balearic Islands, E Spain	Última Hora, October 14, 2018	34.6 mm
	1 driver (? δ) escaped	Mallorca, Balearic Islands, E Spain	Antena 3, October 13, 2018	34.6 mm
	1 driver ($\approx 65\delta$) and 1 occupant ($\approx 65\varphi$) rescued	Cambrils, Tarragona, NE Spain	Diari de Tarragona, October 10, 2018	144.9 mm
	1 driver and 2 occupant rescued	Torrent, Valencia, E Spain	Levante, October 18, 2018	127.8 mm
October 18, 2018	1 driver (? φ) rescued	Beniparrel, Valencia, E Spain	Levante, October 18, 2018	127.8 mm
	1 driver (? φ) rescued	Silla, Valencia, E Spain	Levante, October 18, 2018	127.8 mm
	1 driver (26 δ) rescued	Alcácer, Valencia, E Spain	Levante, October 19, 2018	127.8 mm
October 19, 2018	1 driver (? δ) rescued	Cambrils, Tarragona, NE Spain	Diari Tarragona, October 19, 2018	28.3 mm
October 20, 2018	1 driver (43 δ) dead	Campillos, Málaga, S Spain	ABC, October 21, 2018	259.8 mm
November 15, 2018	1 driver (? δ) rescued	Pilar Horadada, Alicante, E Spain	Europa Press, November 15, 2018	36.5 mm
November 16, 2018	2 drivers rescued	Alboraya, Valencia, E Spain	El Meridiano, November 16, 2018	36.5 mm

**FIGURE 1** Accident distribution by years. Left: number of accidents. Right: number of victims

313 mm in Malaga (Figure 4). Months with greater accident rate usually had also higher rainfall associated with them, especially on those with fatalities; accidents with fatalities in September and October had on average 70 mm of daily rainfall, a value higher than the usual.

The analysis of accidents and fatalities related to precipitation shows that the maximum accident rate occurs with reduced rainfall, although the number of fatalities is low (Figure 5); when rainfall increases the number of victims also does, up to a limit of 30–60 mm, falling above

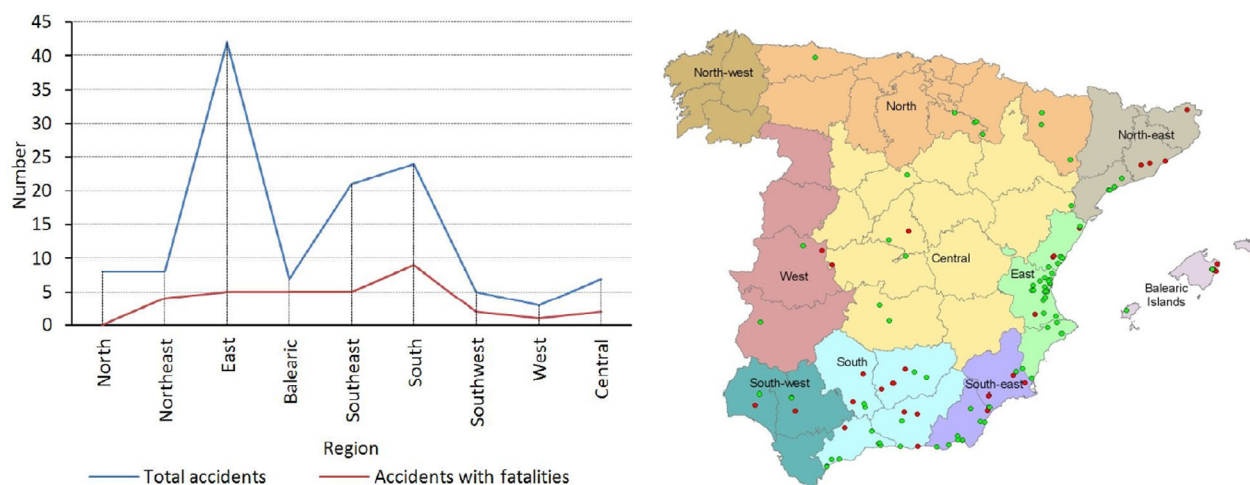


FIGURE 2 Accidents location and frequency. Left: accidents by region. Right: accident location map (red dots indicate accidents with fatalities)

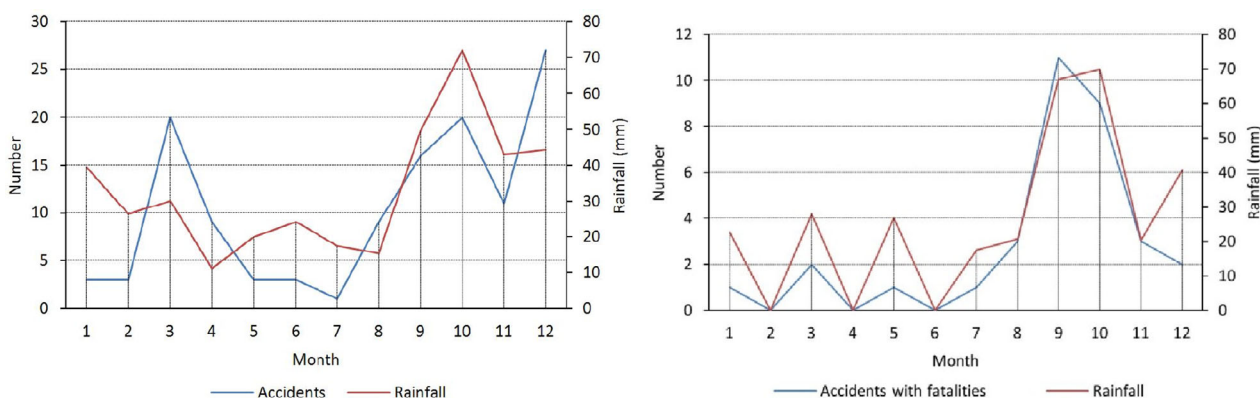


FIGURE 3 Accidents distribution by months and associated daily rainfall. Left: total accidents. Right: accidents with fatalities

those values, and growing up again with very high rainfall values.

Gender information was obtained for 60.5% of the victims, 73.6% of drivers and 38.7% of passengers (Table 2); it was available for all the deceased victims except one passenger (100% of drivers and 97.8% of total fatalities). Age was obtained for all the deceased, but only in 25% of surviving victims; information was available, therefore, for 42% of the victims, 44.2% of the drivers and 100% of the fatalities. Pereira et al. (2016) indicate that age is a factor frequently missing in reports about fatalities caused by floods in Portugal. Sharif, Jackson, Hossain, Bin-Shafique, and Zane (2010) got information on gender of 81% and on age of 58% of victims of motor vehicle-related flood accidents in Texas, and Salvati et al. (2018) data on gender of 79.3% and about the age of 78.1% of flood fatalities in Italy.

Average age of the victims was 48.2 years (Table 2); age increased from victims that had escaped, the younger (41.3), to that deceased, the elder (50.9). Driver's age (50.5) was higher than the average age of the victims, and passengers' lower (43.4). Gender of the victims (Table 2) is 71.9% male and 28.1% female. The percentage of male victims increase for those escaped and rescued, and decreases for the deceased; male victims dominate, but the proportion of deaths among victims is higher in women. There is dominance of male drivers (84.8%) and female passengers (69%).

Average age of male drivers (52.2) was higher than female (39.8) (Table 3); taking into account only deceased drivers, average age increased in male (55.4) but decreased in female (39). In male drivers, the age increases from the victims that had escaped, the younger,

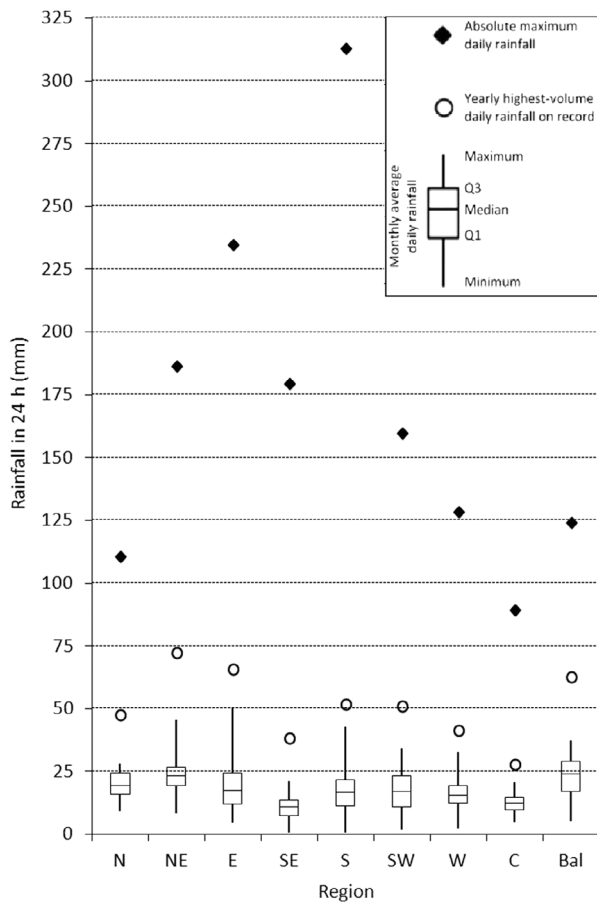


FIGURE 4 Rainfall in 24 hr

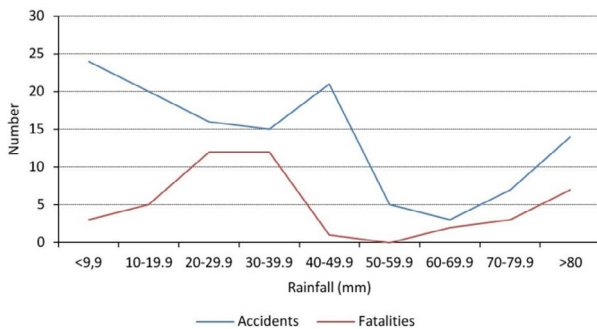


FIGURE 5 Accidents and fatalities related to rainfall

to those deceased, the elder, but in female not; however the total number of female drivers is significantly lower.

As a result, the archetypal driver that crossed an overflowing river in Spain was a male of around 52 years, dying in a third of cases, especially the older ones (Figure 6).

4 | DISCUSSION

Most accidents crossing overflowing rivers occurred in E, S and SE Spain. In these regions rainfall irregularity

favours non-permanent watercourses, which remain dry nearly all year round, but may have torrential flows during a few days a year, after intense rains that produce flash floods. Minor roads frequently cross these watercourses with fords or small drainages, useful almost always but extremely dangerous during heavy rains; this explains to a large extent the concentration of accidents in these regions. Flash floods have also been identified as an important cause of fatalities in Texas, Greece or Portugal (Papagiannaki, Lagouvardos, & Kotroni, 2013; Pereira, Diakakis, Deligiannakis, & Zêzere, 2017; Sharif et al., 2010). Gissing, Oppen, Tofa, Coates, and McAneney (2019) highlight as a risk factor a small upstream catchment length, which may increase the rate of rise of floodwaters.

Months with most accidents in Spain are December, October and March, but those with more fatalities are September and October; most flood events in the North-Western Mediterranean occur between August and November (Llasat et al., 2014). Flood fatalities predominantly occur during autumn in Greece and during winter in Portugal (Pereira et al., 2017); in Spain fatalities occur predominantly in autumn, although December (winter) is the month with more accidents. Mediero, Santillán, Garrote, and Granados (2014) indicate that autumn floods showed decreasing trend in eastern Spain until 2009, but they have been important in the last decade; with the exception of the floods of October 2007, the number of people affected by floods between 2010 and 2013 is higher than between 1997 and 2007 (Gutiérrez, 2016).

As noted above, the highest accident rate occurred with reduced rainfall, increasing with rainfall, decreasing later and increasing again (Figure 4). This seems to be related to a mismatch between the actual and perceived risk. With scarce rainfall risk perception is low, leading to greater drivers' imprudence, although with not much fatalities; as indicated by Hamilton et al. (2016) when water depth is low drivers believe they are capable of crossing it. When the rainfall increases the risk does too, but perception does not do it in parallel, so the number of victims increases. Higher rainfall produces an increased sense of risk, and greater prudence, until very high values are reached, with which the risk becomes extreme, even with awareness about it.

There was over-representation of male victims (68.2% of fatalities, 71.9% of total), consistent with other studies that obtained 60–80% of men among flood victims (Coates, 1999 in Australia; Sharif et al., 2010 in Texas, US; Boissier, 2013 in France; Badoux, Andres, Techel, & Hegg, 2016 in Switzerland; Pereira et al., 2016 in Portugal; Pereira et al., 2017 in Portugal and Greece; Aceto, Pasqua, & Petrucci,

TABLE 2 Gender and age of victims

Victims	Damage	Number		Gender				Data	Age				
		T	%	M	%	F	%		X	M	D	CV	Data
Total	All	200	100.0	87	71.9	34	28.1	60.5	48.2	53.5	22.2	46.0	42.0
	Deceased	45	22.5	30	68.2	14	31.8	97.8	50.9	57.0	21.6	42.4	100
	Rescued	137	68.5	49	73.1	18	26.9	48.9	44.2	50.0	24.1	54.4	26.3
	Escaped	18	9.0	8	80.0	2	20.0	55.6	41.3	41.0	20.1	48.7	22.2
Drivers	All	129	100.0	78	84.8	14	15.2	73.6	50.5	53.0	15.5	30.8	44.2
	Deceased	29	23.2	25	86.2	4	13.8	100.0	53.1	57.0	15.5	29.1	100.0
	Rescued	86	68.8	45	83.3	9	16.7	62.8	48.8	50.0	14.7	30.1	27.9
	Escaped	10	8.0	8	88.9	1	11.1	90.0	41.3	41.0	20.1	48.7	40.0
Passengers	All	75	100.0	9	31.0	20	69.0	38.7	43.4	56.0	31.8	73.4	36.0
	Deceased	16	21.3	5	33.3	10	66.7	93.8	46.9	57.5	29.9	63.7	100.0
	Rescued	51	68.0	4	30.8	9	69.2	25.5	38.3	15.0	35.3	92.2	21.5
	Escaped	8	10.7	0	0.0	1	100.0	12.5	—	—	—	—	0.0

Abbreviations: CV, coefficient of variation; D, standard deviation; Data, percentage of victims with gender/age information; F, female; M, male; M, Median; X, mean.

Drivers	Male				Female				Data
	X	M	D	CV	X	M	D	CV	
All	52.2	56.0	15.7	30.0	39.8	40.5	9.4	23.7	45.6
Deceased	55.4	60.0	15.1	27.2	39.0	40.5	10.4	26.6	100.0
Rescued	50.5	51.5	15.1	30.0	40.5	42.5	9.9	24.4	27.9
Escaped	41.3	41.0	20.1	48.7	—	—	—	—	40.0

TABLE 3 Drivers' age by gender

Abbreviations: CV, coefficient of variation; D, standard deviation; Data, percentage of drivers with age information; M, Median; X, mean.

2017, Salvati et al., 2018 and Petrucci et al., 2018 in Italy; or Vinet, 2017 in Europe). Attending only to drivers, male percentage is even higher, 84.8% of total and 86.2% of the deceased (Table 2); deceased male drivers in Greece were 85.6% (Diakakis & Deligiannakis, 2013), 75.8% in Europe (Jonkman & Kelman, 2005) and 71.2% in Australia (FitzGerald et al., 2010). This over-representation shows a different degree of exposure between males and females (Salvati et al., 2018).

In the 2018 census of drivers of Spain (Figure 7; DGT, 2019) driving licences of passenger cars (the most commonly involved in the analysed accidents) were 54.3% male and 45.7% female; however, gender differences begin to increase from an age of 45, so that at 74 years 83% of driving licences belong to men. This disproportion may explain the higher male accident rate in elderly drivers, but not below 45 years, although the car use rate in Spain is usually somewhat higher in men.

Aparicio, Arenas, Mira, Páez, and Furones (2017) compare the involvement of men and women in traffic accidents in Spain, concluding that the ratio men/women died is around 3.4:1, and that female drivers have more respectful behaviour with traffic regulations, fewer infractions and less risk taking. Many researches about risk perception conclude that females perceived more risks than males (Albentosa, Stephens, & Sullman, 2018; Deffenbacher, Lynch, Filetti, Dahlen, & Oetting, 2003; Diakakis & Deligiannakis, 2013, 2015; Lancaster & Ward, 2002; Sharif et al., 2010; Siegrist et al., 2005; SIRC, 2004).

Average age of victims was 48.2 years, increasing to 50.9 on the deceased. Results vary according to authors and regions: 51 years in France (Boissier, 2013); 20–60 years in Europe and Texas (Jonkman & Kelman, 2005; Sharif et al., 2010); 10–29 and over 60–70 years in the US and Australia (Ashley & Ashley, 2008; FitzGerald et al., 2010); 18–35 for people crossing flooded areas on foot in Iran (Shabanikiya,

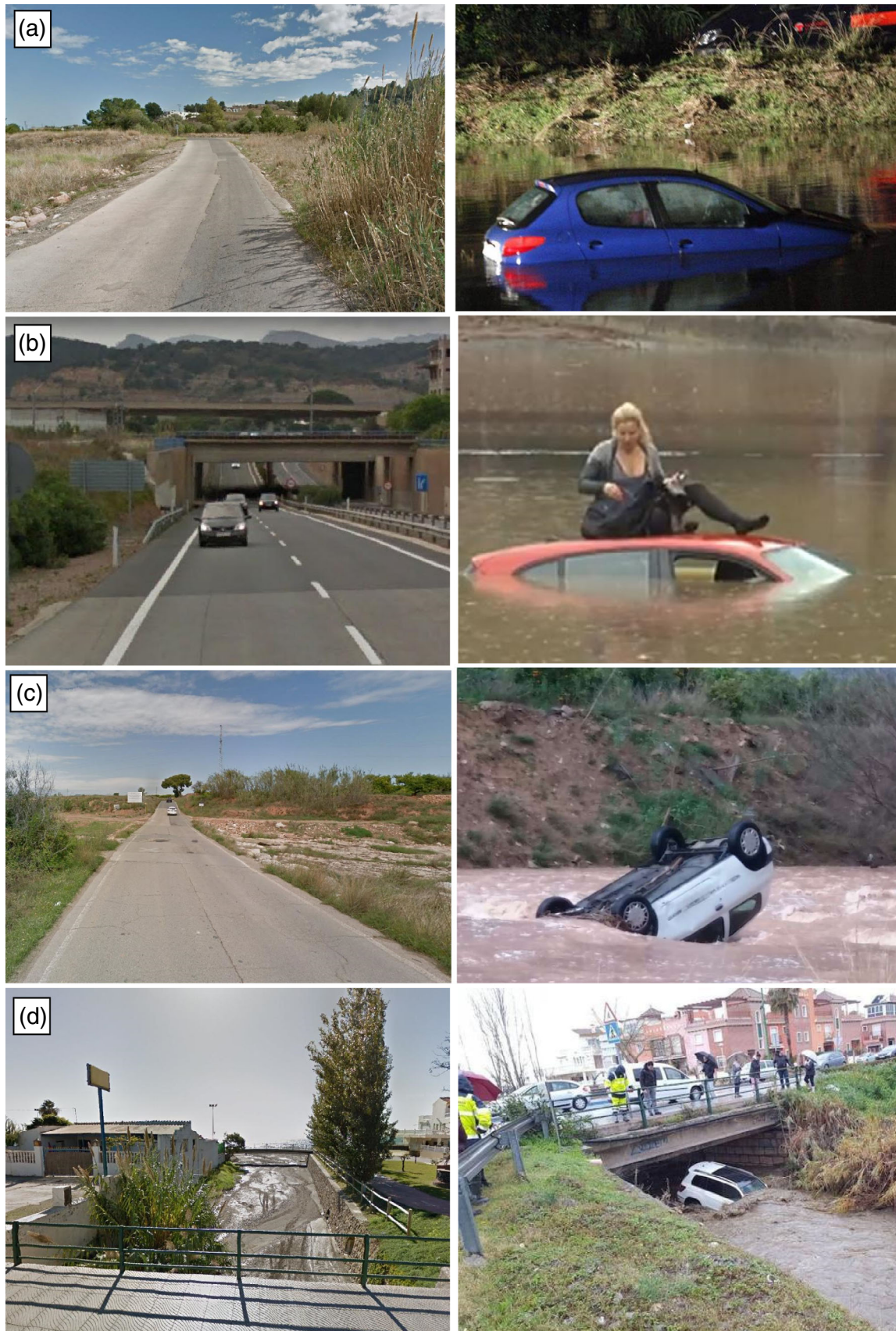


FIGURE 6 Examples of accidents. On the left, the area is shown under usual conditions and on the right during the accident. (a) Onda, Castellón, November 20, 2011 (source: Cadena SER); (b) Sagunto, Valencia, November 26, 2016 (source: Cadena SER); (c) Carraixet, Valencia, January 20, 2017 (source: El Periódico de Aquí); (d) Torre de Mar, Granada, March 02, 2018 (source: Diario Sur); (e) Canonja, Tarragona, April 13, 2018 (source: Diari Tarragona); (f) Cambrils, Tarragona, October 19, 2018 (source: Diari Tarragona)



FIGURE 6 (Continued)

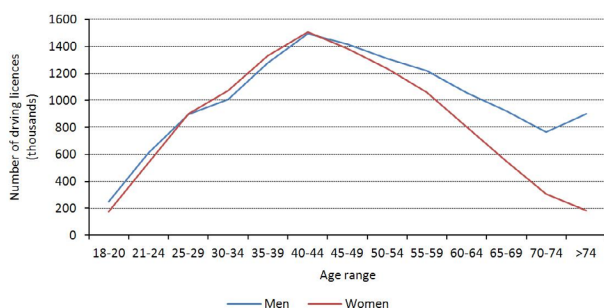


FIGURE 7 Driving licences of passenger cars in 2018 in Spain (data: DGT, 2019)

Seyedin, Haghani, & Ebrahimian, 2014); or 43.4–67.5 years for female in Italy (Aceto et al., 2017). Average age of drivers is 50.5 years, increasing to 53 years on the deceased; this result is consistent with the obtained for Greece, mainly 40–69 years (Diakakis & Deligiannakis, 2013), but different from the obtained in the US, mainly 18–35 years (Drobot et al., 2007). The average age in affected and deceased male drivers (52.2 and 55.6, respectively) is higher than in female (39.8 and 39.3).

There is a demonstrated tendency of young people to have riskier driving behaviour (Amponsah-Tawiah &

Mensah, 2016; Cassarino & Murphy, 2018; Kinnear, Kelly, Stradling, & Thomson, 2009; Lancaster & Ward, 2002; Scott-Parker, Watson, King, & Hyde, 2012; Siegrist et al., 2005; Taubman, Skvirsky, Greenbury, & Prato, 2018). Middle-aged and older drivers are more conservative than younger drivers (Ahmed & Ghasemzadeh, 2018), so accident liabilities reduce with age due to increased maturity and driving experience (Maycock, 2002). However, the results of our research show that the most affected are precisely middle-aged drivers. Drivers learn by receiving feedback from driving (Martinussen, Møller, & Prato, 2014), but most drivers have never crossed an overflowed watercourse, so they lack that feedback; in addition, experience of mature drivers is counterproductive, giving them a false sense of security.

Among the registered victims there are 10 minors, 37% of the occupants and 12% of the total victims of known age. The average age of the minors ranges from 1 to 15 years, with an average value of 7.1 years; 4 of them died (mean age 5.3 years) and 6 were rescued (mean age 8.3 years). It is a remarkable percentage, because it shows that the presence of toddlers in the vehicle does not seem to be a sufficient reason to

discourage drivers from crossing flooded areas, which reinforces the idea of risk undervaluation.

It is noteworthy the presence of 8% of foreign victims, a value near the 10% of foreigners dead in floods in Catalonia, NE Spain, indicated by Nakamura and Llasat (2017). Spain is the second tourist destination in the world, with 81.8 million of international tourists in 2017 (UNWTO, 2018), which largely justifies this high percentage. In addition, drivers have a particular perception of risk in each country (Nordfjærn, Jørgensen, & Rundmo, 2011; Şmşekoğlu, Nordfjærn, & Rundmo, 2012), and even between regions of the same country (Lu, Zhang, Peng, & Sertajur, 2014); affected foreigners might not be familiar with the road environment (Yannis, Golias, & Papadimitriou, 2007), and especially with the irregularity of rainfall in the Mediterranean region.

Hamilton et al. (2016) analyse drivers' willingness to drive through flooded waterways, including attitudinal, social and efficacy beliefs; drivers' perception of risk, and if they think they will not experience negative consequences have great influence, but also their social environment and companions (e.g., partner or friends).

The main cause of river-crossing accidents seems to be overconfidence and overvaluation of driving skills, which reduce the perception of risk (Diakakis & Deligiannakis, 2013; Horswill et al., 2002; Ruin et al., 2007; Siegrist et al., 2005; Terpstra, 2011), underestimating the existing danger and the capacity of the flowing water to drag vehicles (FitzGerald et al., 2010). Flood risk perception is low among the population in Spain (Nakamura & Llasat, 2017), and also in some regions drivers are accustomed to crossing dry watercourses, and this habit leads to an excess of confidence, fatal in cases of overflow.

A vehicle exposed to flooding, after losing stability, becomes buoyant and may be washed away (Martínez-Gomariz, Gómez, Russo, & Djordjević, 2017; Shah, Mustafa, Martínez-Gomariz, Kim, et al., 2019). However, drivers perceive their cars as heavy and stable; water forces, which cause vehicle sliding and buoyancy, are not evident. Vehicle stability on flooded roads depends on water depth and velocity; several studies analyse these factors (Martínez-Gomariz et al., 2017; Martínez-Gomariz, Gómez, Russo, & Djordjević, 2018; Shah, Mustafa, Martínez-Gomariz, Yusof, & Al-Qadami, 2019; Shah, Mustafa, Martínez-Gomariz, Yusof, & Al-Qadami, 2019; Shah, Mustafa, Martínez-Gomariz, Kim, et al., 2019; Smith et al., 2019; Bocanegra, Vallés-Morán, & Francés, 2020). Horizontal water force may produce vehicle sliding, and with a depth around 0.60 m water floating may occur (Kramer, Terheiden, & Wieprecht, 2016); the depth increases buoyancy and reduces the force required to move the vehicles (Smith et al., 2019). Shah et al. (2019)

indicate that a small passenger car (weight ≤ 800 kg) that progresses slowly along a flat flooded road remains stable if the product of water velocity and depth is less than $0.70 \text{ m}^2/\text{s}$. Consequently, when depth increases lower water velocity is required to drag a car, or lower depths were required at high flows (Shah et al., 2019); Teo, Xia, Falconer, and Lin (2012) indicate that deep water at low speeds can cause as much damage as shallow water at high speeds. Martínez-Gomariz et al. (2018) analyse stability criteria for vehicles exposed to flooding, concluding that the most safety is AR&R (Shand, Cox, Blacka, & Smith, 2011); in this criterion the limiting water depths for stability are, depending on vehicle size, 0.3–0.5 m in still water and 0.10–0.20 in high velocity flow. In addition, when rivers overflow there is usually little or no visibility of what is below the water surface, so even shallow waters with moderate flow can make vehicles unstable (Taylor et al., 2019). If the vehicle is surrounded by calm waters, the occupants can usually leave, although with difficulties, but if it is dragged by a rapid flow the chances of escape are greatly reduced (Petrucchi et al., 2018).

Drivers frequently think that their displacements are essential, so when weighing the desire to move and the risk assumed the latter is underestimated; the first impulse is to cross the river and not to turn around. Sometimes the urgency is certain, but in the vast majority of cases this reckless behaviour is not justified.

The characteristics of the road also seem to influence the accident rate. Gissing et al. (2019) indicate as usual characteristics associated with accidents in Australia the absence of roadside barricades and lighting, dipping road grades, lack of curb and guttering and difficulties to turn around.

Another problem is that social communication about flood risk is insufficient (Nakamura & Llasat, 2017). The media only pay attention to floods when they have already occurred, and especially when there are fatalities or major damages, but there is no real social awareness of this risk; even public agencies give permits for buildings or infrastructures in flood prone areas. Many fatalities during floods are related to motor vehicles (Boissier, 2013; Diakakis & Deligiannakis, 2015; Jonkman & Vrijling, 2008; Petrucci et al., 2019; Salvati et al., 2018; Sharif et al., 2010; Smith et al., 2019; Vinet, 2017), but there is not enough social awareness about that. Pereira et al. (2017) indicate for Greece and Portugal that although fatalities inside buildings have been reduced, vehicle-related deaths have been rising, and our results for Spain also found an increase in the number of accidents.

It is economically non-viable to build bridges or big drainages in all watercourse crossings. For example, in E, S and SE Spain, the regions with more accidents,

there are a lot of watercourses with riverbeds that can exceed 100 m width, where water flows only a few days a year; a bridge over them is a large-scale work, reasonable on main roads, but not on minor roads. Consequently, the presence of dangerous crossing points is unavoidable.

It is desirable that the authorities signalise dangerous crossings, and close them during intense rains, but in practice, it is impossible to do throughout the country; it can be done on major roads but not on all local and dirt roads. Signalling is only effective if it is placed just during the flooding, which is impossible at all risk points in the event of a flash flood. In addition, signalling does not guarantee that drivers do not cross flooded sections; several of the recorded accidents occurred on roads closed to traffic. Similarly, most people drowned in US after hurricane Floyd had received severe weather warnings (Yale et al., 2003).

Environmental education through traditional knowledge transfer, reinforcement of the belief in the risk of climate change or influencing on the perception of risk does not seem to be effective to achieve adaptive behaviours (Choonm, Ong, & Tan, 2018; Grothmann & Reusswig, 2006; Li, Juhsáz-Horváth, Harrison, Pintér, & Rounsevell, 2017); even flood victims do not perceive climate change as a personal and direct risk (Whitmarsh, 2008). Current campaigns are ineffective and mainly reactive, so it is necessary to change the methods, including new information that, if relevant and persuasive, can change behaviours (Bamberg, Ajzen, & Schmidt, 2003).

5 | RECOMMENDATIONS

Intense rainfall episodes may produce watercourses overflowing; crossing by car in these circumstances, even on a road, is extremely dangerous. During these rainfall events it is important the response of the authorities, but also the behaviour of the drivers; however, many drivers, most mature men, try to cross-overflowing rivers and flooded sections. These behaviours may be due to underestimation of risks, overconfidence, overvaluation of driving skills, prepotency, an excess of trust in the authorities, ignorance about vehicle drag and buoyancy risks and social pressures.

It is necessary to raise awareness among the authorities and citizens, establish adequate protocols for action and, above all, a behavioural adaptation of the drivers. Some possible actions are:

- Improve road safety redesigning river crossings and installing warning signs (Diakakis & Deligiannakis, 2015), reinforcing the role of the provincial institutions (Sánchez, Escribano, & Tejada, 2018), increasing funding

to reduce the vulnerability of the road network against hazards (Voumard et al., 2018) and foreseen diversion routes in the most critical points (Jenelius, 2009; Voumard et al., 2018).

- Promote citizens' awareness about hazards, especially about flood risk, to encourage a self-protective behaviour (Grothmann & Reusswig, 2006; Nakamura & Llasat, 2017; Sharif et al., 2010), with special attention to the most prone regions. It is possible to implement advertising campaigns, similar to those carried out to raise awareness about traffic accidents or dangers of drink-driving.

- Reinforce warning campaigns to the population during rainfall events that can lead to flooding or to river overflowing, using media and social networks.

- Strengthen real-time information for on-board units or smartphone applications (Park, Haghani, Samuel, & Knodler, 2018; Su, Huang, & Li, 2016), which may warn about extreme rains and flood risks.

- Include hazard perception elements in the driving theory test (Sexton, 2010), especially about the danger of crossing overflowing rivers; drivers must internalise that they cannot drive through flooded areas (Jonkman & Kelman, 2005). Driving courses should emphasise on safety skills more than on driving skills, to avoid creating a false sense of self-confidence (Sümer, Özkan, & Lajunen, 2006).

- Education, starting from schoolchildren, should disassociate driving task from masculine roles (Albentosa et al., 2018); it is not necessary to take risks driving for being a man.


- Promote information to foreign residents and visitors about the risks associated with flooding, with the collaboration of embassies, town halls, travel agencies and car rental agencies.

In conclusion, it is necessary a greater effort of the authorities to better manage risks associated with river overflow, which will probably increase in the future, but also a change in drivers' behaviour, which should be promoted by all the authorities, not only traffic but also educational.

DATA AVAILABILITY STATEMENT

Data sharing is not applicable to this article as no new data were created or analyzed in this study.

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